

# Characteristics in a traumatic spinal cord injury population

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## ABSTRACT

**INTRODUCTION:** The aim of this study was to describe core characteristics in a Danish population of rehabilitated traumatic spinal cord injury (SCI) patients.

**METHODS:** Retrospectively, data were extracted from a database on all traumatic patients with SCI admitted to the Spinal Cord Injury Centre of Western Denmark having sustained an injury to the spinal cord between 1 January 1997 and 1 January 2017. Age is presented as medians and interquartile ranges (IQR).

**RESULTS:** A total of 584 (women = 122; men = 462) traumatic patients with SCI with a median age of 42.9 years (26.4–58.3 years) were identified of whom 390 underwent surgery (SG) and 55 were treated conservatively forming a conservative group (CG). The acute treatment regime was unknown in 139 patients with SCI. Patients in the CG were significantly older (median 63.6 years (IQR: 39.1–71.5)) than patients in the SG (median 52.8 years (IQR: 37.2–67.2)),  $p = 0.02$ . The relative risk (RR) of fractures was higher in the SG (RR = 2.74 (1.91–3.95),  $p < 0.0001$ ). The initial American Spinal Injury Association Impairment Scale (AIS) grades (A, B, C and D) differed significantly (Kruskal-Wallis test,  $p < 0.02$ ) with a higher frequency of AIS D in the CG. Fewer persons with a cervical than with a non-cervical level of injury underwent spinal surgery (RR = 0.65 (0.54–0.77),  $p < 0.0004$ ).

**CONCLUSIONS:** In a Danish population of patients with traumatic SCI, we observed a preponderance for surgical treatment among a) younger patients, b) patients with vertebral fractures, and c) more severe SCI cases.

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**TRIAL REGISTRATION:** The study was conducted in accordance with the Helsinki II Declaration. Data were obtained with permission from the Danish Data Protection Agency (record number 2012-41-0572).

Traumatic spinal cord injury (SCI) is accompanied by substantial acute and chronic morbidity and raised mortality [1, 2]. The chronic course of the condition is dominated by the loss of motor and sensory function, but also includes symptoms such as autonomic dysreflexia and impairment of bowel and bladder control as well as pain and spasticity resulting in significant loss of quality of life [3–5]. In the acute phase of traumatic SCI, surgical treatment targeting spine stability and decompression is often opted for, although a conservative approach may be chosen as well [6].

Studies have suggested that the surgical impact on neurological improvement is marginal in complete traumatic SCI [7, 8]. Consequently, it has been suggested that surgeons should more willingly surgically decompress acute traumatic non-complete SCI [9].

To explore present treatment of traumatic SCI, this study aimed to identify core characteristics in a Danish population of rehabilitated patients with SCI.

## METHODS

### Participants

All patients with traumatic SCI with rehabilitation potential in Western Denmark, covering an area of approximately three million citizens, are admitted to the Spinal Cord Injury Centre of Western Denmark for neurorehabilitation.

### Procedure

Prospectively, we manage a database of all patients with SCI in Western Denmark, including both the adult and paediatric SCI population. Data are obtained and registered in accordance with the International Spinal Cord Injury Core Data Set [10]. From our database (REDCap), we extracted all patients with traumatic SCI who had sustained an injury between 1 January 1997 and 1 January 2017.

### Statistical analyses

The following core variables were included: Date of injury, gender, present age, age at injury, vertebral fracture, spine surgery, associated injuries and mechanical ventilator dependency. Furthermore, we extracted information regarding American Spinal Injury Association Impairment Scale (AIS) grade (A, B, C and D) and neurological level of injury (NLI) obtained during acute in-hospital stay, at discharge and at last follow-up [11].

Vertebral fractures were defined as a binary yes/no variable and determined based on X-ray/CT-verified fractures of the spinal column. Fractures included traumatic disruption of the intervertebral discs [12].

Spine surgery was defined binarily as a yes/no variable as any surgical intervention aiming to stabilise and/or decompress. Associated injuries were defined as any injury to any other organ system induced by the trauma. All statistics and analyses were performed using STATA 15.0 and SPSS.

## ORIGINAL ARTICLE

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Age is presented as medians and interquartile ranges (IQR). All other variables are presented as numbers and frequencies. Furthermore, data have been grouped by AIS grade and by injury severity in accordance with the recommendations from the International Spinal Cord Injury Core Data Set [10]. Student's t-test was applied to normally distributed data and non-parametric tests to categorical and dichotomised data. A 95% significance level was used for all calculations. Handling of the missing values: for computing of the regressions, we excluded all patient entries with missing data for a given variable from computation of that particular regression.

*Trial registration:* The study was conducted in accordance with the Helsinki II Declaration. Data were obtained with permission from the Danish Data Protection Agency (record number 2012-41-0572).

**RESULTS**

**Population characteristics**

A total of 584 patients (female = 122; male = 462) sustaining traumatic SCI from 1 January 1997 to 1 January 2017 were identified. All variables were not complete for all patients; hence, the total number of included patients varied for each variable.

A total of 390 patients underwent surgery and 55 persons did not. Acute treatment was unknown in 139 patients.

*The surgical group*

In the surgical group (SG), 158 (53%) patients suffered from cervical injuries. In all, 304 (78%) were male. Furthermore, the SG counted 365 (96%) patients who suffered from vertebral fracture, 297 (84%) with no associated injuries and 97 (36%) who had complete neurological injury (Table 1).

*The conservative group*

In the conservative group (CG), 35 (81%) patients suffered from cervical injuries, 19 (35%) from vertebral fracture and three (8%) sustained a complete neurological injury (Table 1).

**Comparison of core data between treatment strategies**

CG patients were significantly older (median 63.6 years (IQR: 39.1-71.5),  $p = 0.02$ ) than SG patients (median 52.8 (IQR: 37.2-67.2)). The proportion of patients with fractures was higher among those being treated with surgery (relative risk = 2.74, 95% confidence interval: 1.91-3.95,  $p = 0.0001$ ). The proportion of patients who had associated injuries and the share of mechanically ventilated patients did not differ between the SG and the CG group.

**Analysis of distribution of American Spinal Injury Association Impairment Scale grades and injury severity**

The distribution of AIS grades between SG and CG patients differed significantly (Kruskal Wallis test,  $p < 0.02$ ). A Dunn test showed that AIS D patients were represented at significantly higher frequencies than AIS A, B and C in the CG.

**Predictors of American Spinal Injury Association Impairment Scale grades and neurological level improvement**

The regressions were computed from eight independent variables (age, gender, vertebral fractures y/n, associated injuries y/n, surgical treatment y/n, baseline AIS, baseline NLI and ventilator dependency). For the AIS improvement models, a total of 237 patients were included, yielding 30 patients per predicting variable and categories. As for the models of NLI, improvement was recorded in a total of 216 patients, yielding 27 patients per predicting variable and categories.

Both linear and logistic regressions with AIS and NLI improvements as continuous and dichotomous outcomes were computed and did not yield satisfactory  $R^2$ -values. None of the acquired variables seem to predict long-term improvement after traumatic SCI.

**TABLE 1 /** Characteristics of traumatic spinal cord injury patients who underwent surgery as compared to non-surgically treated.

	Surgery, n (%)	Conservative treatment, n (%)	Relative risk, median (95%CI)	p-value
<i>Level of injury</i>				0.0004 <sup>a</sup>
Cervical	158 (53)	35 (81)	0.65 (0.54-0.77)	
Non-cervical	142 (47)	8 (19)		
<i>Gender</i>				0.11 <sup>a</sup>
Female	86 (22)	7 (13)	1.73 (0.85-3.55)	
Male	304 (78)	48 (87)		
<i>Associated injuries</i>				0.44 <sup>a</sup>
Yes	55 (16)	6 (12)	1.35 (0.61-2.98)	
No	297 (84)	46 (89)		
<i>Vertebral fractures</i>				< 0.0001 <sup>a</sup>
Yes	365 (96)	19 (35)	2.74 (1.91-3.95)	
No	20 (4)	36 (66)		
<i>Mechanical ventilation</i>				0.97 <sup>a</sup>
Yes	20 (6)	3 (6)	1.02 (0.31-3.31)	
No	320 (94)	49 (94)		
<i>AIS distribution</i>				< 0.02 <sup>b</sup>
A	97 (36)	3 (8)		
B	12 (4)	1 (3)		
C	53 (20)	4 (11)		
D	109 (40)	28 (78)		

AIS = American Spinal Injury Association Impairment Scale; CI = confidence interval.

a) Fisher's exact test.

b) Kruskal-Wallis test.

## DISCUSSION

In this descriptive study of a 20-year historic population initially examined and treated at the Department of Neurosurgery, Aarhus University Hospital, after acute traumatic SCI followed by primary neurorehabilitation at a highly specialised rehabilitation hospital, we found that surgically treated patients with SCI are more prone to suffer from vertebral fractures than conservatively treated patients are. We found that most patients in our population were managed surgically. This is in accordance with a recent prospective study on core data from Scandinavia reporting that 96% of patients underwent surgery [13]. However, the higher share recorded in their study may be due to a lower number of included patients (n = 45).

Traditionally, surgery will be recommended for traumatic SCI with fractures [14, 15], which is reflected in our findings, where not having a fracture increased the odds of not having surgery.

In our study, we found a trend towards patients with AIS A undergoing surgical treatment at a higher frequency than AIS D patients. Conservatively treated patients with SCI were older than the surgically treated patients.

Whilst literature is sparse on the matter of conservative versus surgical treatment, a systematic review found that 62% of conservatively treated patients suffered from complete injuries, whereas 45% of surgically treated patients suffered from complete injuries [7]. These findings run contrary to the trend observed in our dataset that AIS A patients are more likely to be treated by surgery.

The present findings suggest that surgeons still manage some AIS D patients conservatively, whereas AIS A patients are generally treated by surgery. Surgical decision-making is complex, and decisions are made on a case-by-case basis. However, this result seems to oppose a dogma that improvement is more likely when treating incomplete than complete traumatic SCI with decompressive surgery [9].

Conservatively treated patients were significantly older than patients undergoing surgery, which might reflect a less aggressive intervention strategy for the older patients.

Surgically treated patients were more prone to be designated the T1-S5 AIS A, B, C groups, which might reflect a lack of conservative immobilisation techniques in the acute phase for this part of the spine.

### Strengths and weaknesses

The AIS grades are categorical and hierarchical. When we treat this variable as categorical, we do not consider this inherent continuum between the grades, leading to

potential type-II error due to insensitivity. However, one could argue that the continuum might not be restricted to one dimension, and that the complexity of using these categories is debatable and is a potential point of criticism of the AIS scale in general [16]. This argument supports a change in our prospective data acquisition towards a non-categorical linear scale such as the newly introduced Spinal Cord Ability Ruler [17].

Data were not complete for all patient entries in the database, which may also have introduced bias. The extent and direction of such bias are less predictable.

Data were obtained from a 20-year period. Changes in both pre-hospital and acute hospital management and possibly also changes in the referral pattern will have occurred in that period. However, data did not allow for controlling for such time-dependent variability. These changes may have lowered the risk of anaesthesiologic problems, etc, meaning that surgery might be a safer option now than 20 years ago. Furthermore, enhanced control and handling of the multi-traumatised patient, improved paraclinical support, better paramedics coverage, etc. are in place now than was the case at the beginning of the study period.

### Should fracture remain the primary indication of surgery?

The odds of having vertebral fractures were significantly increased in the surgical group. Meanwhile, recent studies have hypothesised that spinal cord perfusion pressure is highly dependent on the dural casing of the spinal cord, which in turn means that oedema below the dura might compromise the blood supply to the spinal cord [18, 19]. This suggests that oedema of the spinal cord itself may potentially be an independent indication for surgery, as the patients might benefit from neurologically from a reduction in intra-spinal pressure [20].

More detailed models encompassing paraclinical visualisation in the assessment of the spinal cord integrity, comprehensive clinical scoring systems and paraclinical biomarkers are needed in order to select the right patient for the better treatment option.

## CONCLUSIONS

In Danish rehabilitated patients with traumatic SCI, surgical treatment was preferred more often in younger patients, in patients with vertebral fractures, and in patients who had sustained more severe SCI.

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